LEAD SOIL TREND ANALYSIS
THROUGH DECEMBER, 2004
EVALUATION BY INDIVIDUAL QUADRANT
Herculaneum Lead Smelter Site
Herculaneum, Missouri

Tetra Tech EM Inc. (Tetra Tech) was tasked by the U.S. Environmental Protection Agency (EPA) Region 7 Enforcement/Fund Lead Removal program to conduct a trend analysis of soil lead concentrations at selected locations within Herculaneum, Missouri (City). Specifically, the Tetra Tech Superfund Technical Assessment and Response Team (START) 2 was requested to review and analyze data that would enable EPA to determine if soil lead concentrations were increasing over time at a variety of locations within the City. Tetra Tech had previously performed this analysis and was requested to repeat the analysis using the most current sampling data by evaluating the trends for each sampling quadrant. The assessment was conducted under authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the Superfund Amendments and Reauthorization Act of 1986. The project was assigned under START Contract No. 68-S7-01-41, Task Order No. 0027.

Tetra Tech focused its analysis on one data set called "Recontamination." This data set includes results from a number of residential properties. The data were collected from four different quadrants at each property, and additional data for several properties came from samples collected in driveway areas outside the quadrants. Lead concentrations were estimated at each location at approximately monthly intervals from the time removal activities were completed until December 2004 (sampling round 19). Due to the sequence of removal activities, not all properties underwent the same number of sampling events; the number of events ranged from 5 to 13 events per quadrant for individual properties. At many locations, some intervals within the series were omitted because of weather or access restrictions. The lead concentrations were determined by use of a portable X-ray fluorescence (XRF) instrument. Samples were collected and analyzed in accordance with the quality assurance project plan (QAPP) dated September 11, 2001.

This document presents the methods used to evaluate changes in soil lead concentrations following the removal activities, and the results of this analysis.

Methods

Temporal trends in lead concentrations for 17 properties are summarized in Table 1 and Figure 1. Trend tests were conducted for each property using all data collected from round 7 (August 2002) through round 19 (December 2004). The non-parametric Mann-Kendall test was used to evaluate temporal trends for each sampled quadrant at the individual properties. The Mann-Kendall test is a widely used statistical test for detecting monotonic trends (that is, trends that are either increasing or decreasing) in time-series of data (Gilbert 1987; Helsel and Hirsch 1992; Gibbons 1994). Because the Mann-Kendall test uses only the relative magnitude of the data rather than their measured values, it has a number of desirable properties: the data need not be normally distributed; and the test is not significantly affected by outliers, missing data, or censored data. Censored data are treated in the Mann-Kendall test by setting all non-detect values to a concentration slightly below the minimum detected concentration. It should be noted that a minimum of four sampling events are required to perform this test, so properties with fewer than four rounds of sampling were not evaluated. Ten properties that have not been sampled over the last several rounds were also excluded from analysis. These included House Numbers 1, 2, 4, 8, 10, 11, 13, 14, 15, and 23.

Results

The analysis of the temporal trends in lead concentrations identified 16 of the 17 properties as containing at least one quadrant with a statistically significant increasing trend: House Numbers 20, 101, 102, 5, 6, 22, 24, 12, 17, 21, 16, 19, 9, 18, 3, and 7 (Table 1, Figure 1). In the trend plots provided in Figure 1, detected data are shown as solid symbols and censored data are shown as open symbols. Four properties had temporal trends with increasing lead concentrations in all four quadrants: House Numbers 20, 5, 12, and 9. Four properties had temporal trends with increasing lead concentrations in three of four quadrants: House Numbers 22, 16, 19, and 7. Five properties had temporal trends with increasing lead concentrations in two of four quadrants: House Numbers 101, 102, 24, 17, and 21. The remaining houses identified above had only one quadrant with a statistically significant increasing temporal trend in lead concentration. Only one property, House Number 76, showed no statistically significant trend in lead concentrations, although data were only collected for two quadrants. No quadrants from any property showed a statistically significant decreasing trend in lead concentration.

A spatial analysis of those properties with at least two quadrants with a statistically significant increasing temporal trend in lead concentration did not identify any clear relationship between the house location and the haul routes. All properties within 0.45 mile of the smelter, except for House Number 76, had at least one quadrant with a statistically significant trend.

References:

Gibbons, R. D. 1994. *Statistical Methods for Groundwater Monitoring.* John Wiley & Sons, Inc. New York, New York.

Gilbert, R. O. 1987. *Statistical Methods in Environmental Pollution Monitoring.* John Wiley & Sons, Inc. New York, New York.

Helsel, D. R. and R. M. Hirsch. 1992. *Statistical Methods in Water Resources.* Elsevier. New York, New York.

TABLE 1
RESULTS OF STATISTICAL TESTING FOR MONOTONIC TRENDS (MANN-KENDALL TEST) IN LEAD CONCENTRATION INDIVIDUAL QUADRANTS FOR SAMPLING ROUNDS 7 THROUGH 19
HERCULANEUM LEAD SMELTER SITE - HERCULANEUM, MISSOURI

Distance From Smelter[1]	House Number	Quadrant	Number of Sampling Events[2]	Number of Detected Samples	Sampling Event		Mann-Kendall Test Statistic[3] (S)	Probabilit y > S	Trend Significant? [4] (Yes/No)	Direction of Trend
					First	Last				
0.10	76	Q1	6	6	09/22/2003	12/16/2004	7	0.136	No	N/A
		Q2	6	6	09/22/2003	12/16/2004	9	0.068	No	N/A
0.20	20	Q1	12	12	08/23/2002	12/16/2004	42	0.004	**Yes**	**Increasing**
		Q2	12	12	08/23/2002	12/16/2004	34	0.015	**Yes**	**Increasing**
		Q3	12	12	08/23/2002	12/16/2004	52	0.000	**Yes**	**Increasing**
		Q4	12	12	08/23/2002	12/16/2004	40	0.006	**Yes**	**Increasing**
	101	Q1	5	5	12/22/2003	12/16/2004	4	0.242	No	N/A
		Q2	5	4	12/22/2003	12/16/2004	6	0.117	No	N/A
		Q3	5	5	12/22/2003	12/16/2004	8	0.042	**Yes**	**Increasing**
		Q4	5	5	12/22/2003	12/16/2004	10	0.008	**Yes**	**Increasing**
	102	Q1	5	5	12/22/2003	12/16/2004	10	0.008	**Yes**	**Increasing**
		Q2	5	5	12/22/2003	12/16/2004	4	0.242	No	N/A
		Q3	5	5	12/22/2003	12/16/2004	8	0.042	**Yes**	**Increasing**
		Q4	5	5	12/22/2003	12/16/2004	6	0.117	No	N/A
0.25	5	Q1	12	9	08/23/2002	12/16/2004	46	0.002	**Yes**	**Increasing**
		Q2	12	11	08/23/2002	12/16/2004	44	0.003	**Yes**	**Increasing**
		Q3	12	12	08/23/2002	12/16/2004	49	0.001	**Yes**	**Increasing**
		Q4	12	12	08/23/2002	12/16/2004	38	0.008	**Yes**	**Increasing**
	6	Q1	12	12	08/23/2002	12/16/2004	14	0.134	No	N/A
		Q2	12	12	08/23/2002	12/16/2004	36	0.011	**Yes**	**Increasing**
		Q3	12	12	08/23/2002	12/16/2004	12	0.150	No	N/A
		Q4	12	12	08/23/2002	12/16/2004	12	0.150	No	N/A
	22	Q1	11	11	08/23/2002	12/16/2004	15	0.110	No	N/A
		Q2	11	11	08/23/2002	12/16/2004	35	0.006	**Yes**	**Increasing**
		Q3	11	11	08/23/2002	12/16/2004	30	0.015	**Yes**	**Increasing**
		Q4	11	11	08/23/2002	12/16/2004	33	0.009	**Yes**	**Increasing**
	24	Q1	9	9	11/07/2002	09/23/2004	14	0.090	No	N/A
		Q2	9	9	11/07/2002	09/23/2004	18	0.038	**Yes**	**Increasing**
		Q3	9	9	11/07/2002	09/23/2004	10	0.179	No	N/A
		Q4	9	8	11/07/2002	09/23/2004	19	0.030	**Yes**	**Increasing**
0.40	12	Q1	13	10	08/23/2002	12/16/2004	41	0.010	**Yes**	**Increasing**
		Q2	13	8	08/23/2002	12/16/2004	38	0.013	**Yes**	**Increasing**
		Q3	13	11	08/23/2002	12/16/2004	39	0.013	**Yes**	**Increasing**
		Q4	13	12	08/23/2002	12/16/2004	28	0.051	**Yes**	**Increasing**
	17	Q1	12	12	08/23/2002	12/16/2004	40	0.005	**Yes**	**Increasing**
		Q2	12	12	08/23/2002	12/16/2004	30	0.028	**Yes**	**Increasing**
		Q3	12	12	08/23/2002	12/16/2004	22	0.071	No	N/A
		Q4	12	10	08/23/2002	12/16/2004	23	0.064	No	N/A
	21	Q1	8	6	08/23/2002	12/16/2004	9	0.169	No	N/A
		Q2	8	8	08/23/2002	12/16/2004	12	0.089	No	N/A
		Q3	8	8	08/23/2002	12/16/2004	16	0.031	**Yes**	**Increasing**
		Q4	8	8	08/23/2002	12/16/2004	22	0.003	**Yes**	**Increasing**

Distance From Smelter[1]	House Number	Quadrant	Number of Sampling Events[2]	Number of Detected Samples	Sampling Event		Mann-Kendall Test Statistic[3] (S)	Probability > S	Trend Significant? [4] (Yes/No)	Direction of Trend
					First	Last				
0.50	16	Q1	10	6	09/25/2002	12/16/2004	-5	0.364	No	N/A
		Q2	10	4	09/25/2002	12/16/2004	30	0.003	**Yes**	**Increasing**
		Q3	10	5	09/25/2002	12/16/2004	21	0.036	**Yes**	**Increasing**
		Q4	10	6	09/25/2002	12/16/2004	27	0.008	**Yes**	**Increasing**
	19	Q1	12	11	08/23/2002	12/16/2004	31	0.024	**Yes**	**Increasing**
		Q2	12	9	08/23/2002	12/16/2004	13	0.141	No	N/A
		Q3	12	10	08/23/2002	12/16/2004	31	0.024	**Yes**	**Increasing**
		Q4	12	11	08/23/2002	12/16/2004	35	0.013	**Yes**	**Increasing**
0.54	9	Q1	12	12	08/23/2002	12/16/2004	31	0.024	**Yes**	**Increasing**
		Q2	12	12	08/23/2002	12/16/2004	29	0.031	**Yes**	**Increasing**
		Q3	12	12	08/23/2002	12/16/2004	30	0.028	**Yes**	**Increasing**
		Q4	12	11	08/23/2002	12/16/2004	33	0.018	**Yes**	**Increasing**
0.60	18	Q1	13	13	08/23/2002	12/16/2004	16	0.131	No	N/A
		Q2	13	12	08/23/2002	12/16/2004	4	0.196	No	N/A
		Q3	13	13	08/23/2002	12/16/2004	31	0.037	**Yes**	**Increasing**
		Q4	13	13	08/23/2002	12/16/2004	26	0.062	No	N/A
0.75	3	Q1	13	10	08/23/2002	12/16/2004	-7	0.186	No	N/A
		Q2	13	11	08/23/2002	12/16/2004	33	0.029	**Yes**	**Increasing**
		Q3	13	12	08/23/2002	12/16/2004	-2	0.199	No	N/A
		Q4	13	12	08/23/2002	12/16/2004	27	0.056	No	N/A
0.80	7	Q1	13	13	08/23/2002	12/16/2004	14	0.146	No	N/A
		Q2	13	11	08/23/2002	12/16/2004	39	0.013	**Yes**	**Increasing**
		Q3	13	10	08/23/2002	12/16/2004	29	0.045	**Yes**	**Increasing**
		Q4	13	9	08/23/2002	12/16/2004	46	0.004	**Yes**	**Increasing**

Notes:

[1] Properties are ordered as a function of increasing distance from the smelter.

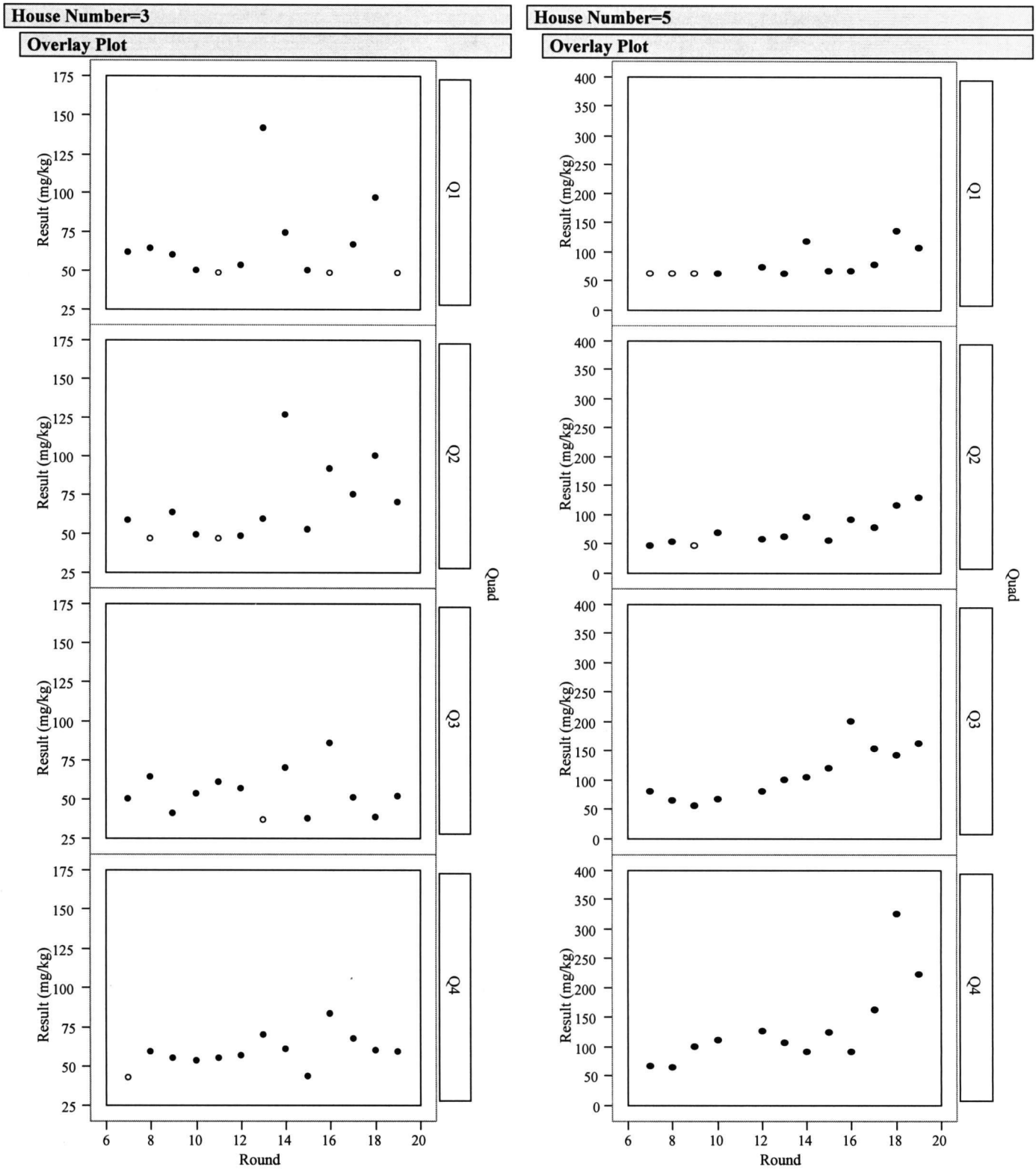
[2] Trend tests were not conducted for properties with fewer than four rounds of sampling.

[3] All censored (nondetect) measurements were set equal to a concentration slightly lower than the minimum detected value.

[4] Monotonic trends are significant for probabilities less than or equal to 0.05; significant negative values for the Mann-Kendall test statistic indicate that trends are decreasing; and significant positive values for the Mann-Kendall test statistic indicate that trends are increasing.

NA No significant trend identified.

FIGURE 1. Lead Concentration Trends From Round 7 Through 19



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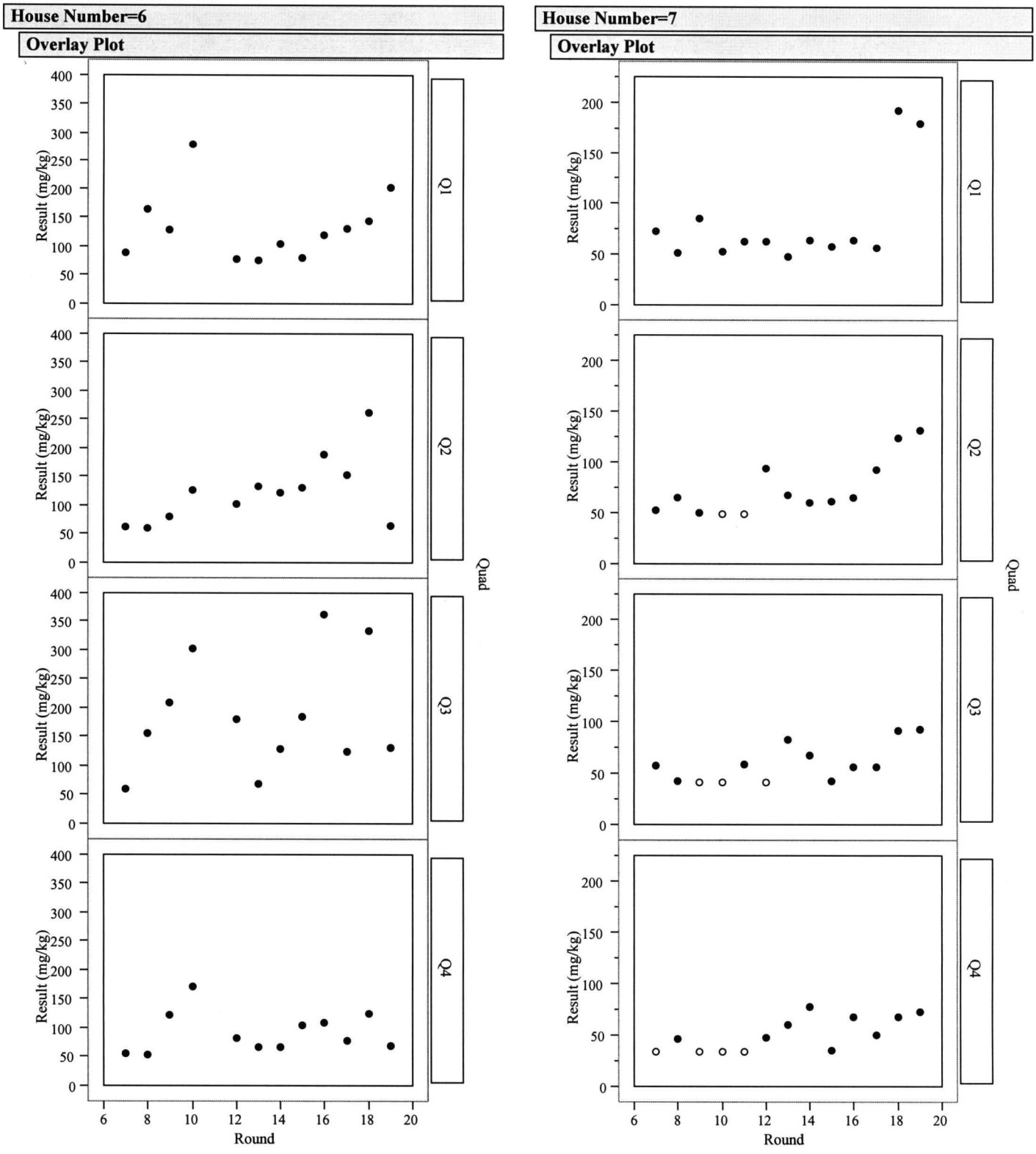

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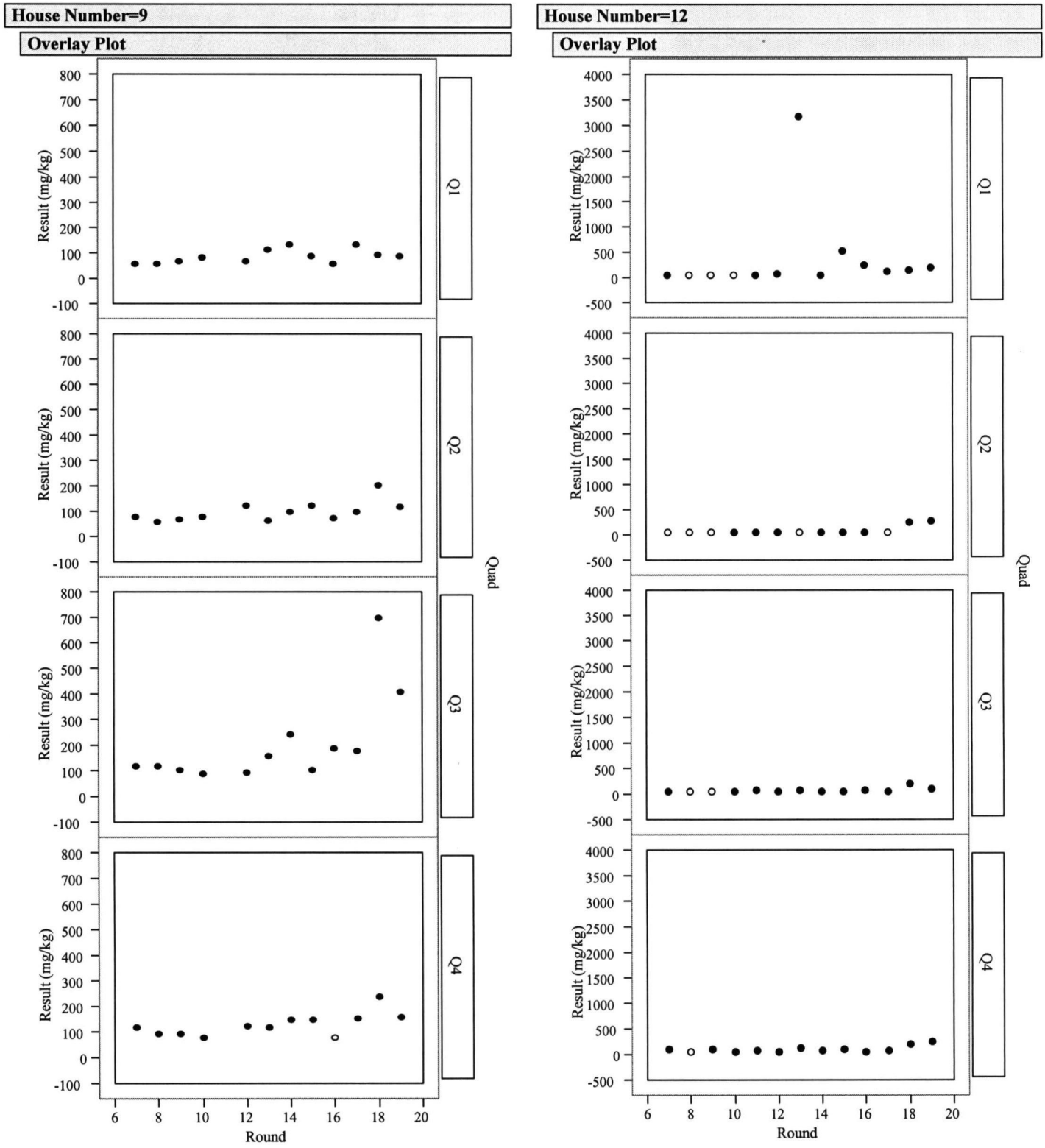

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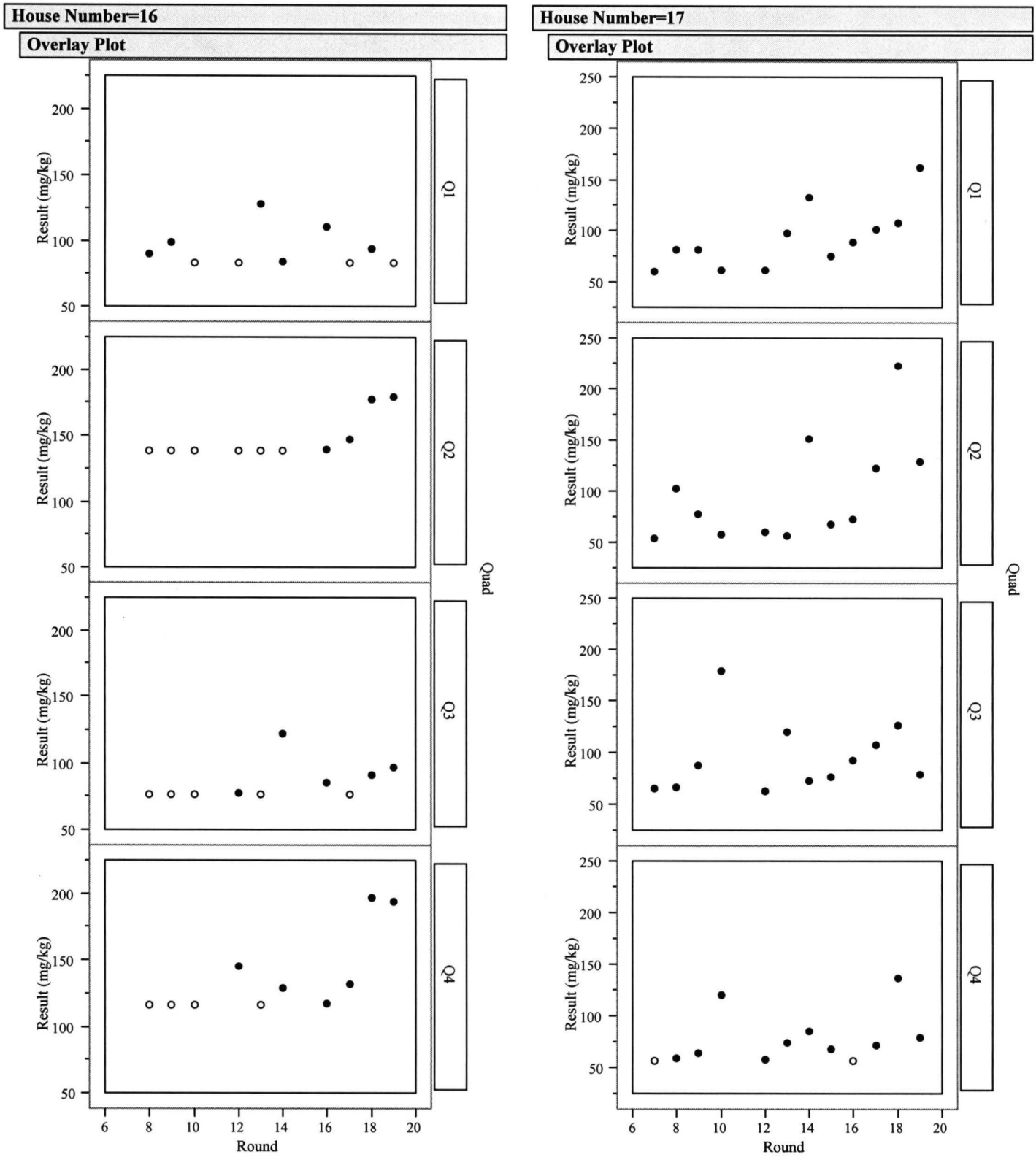

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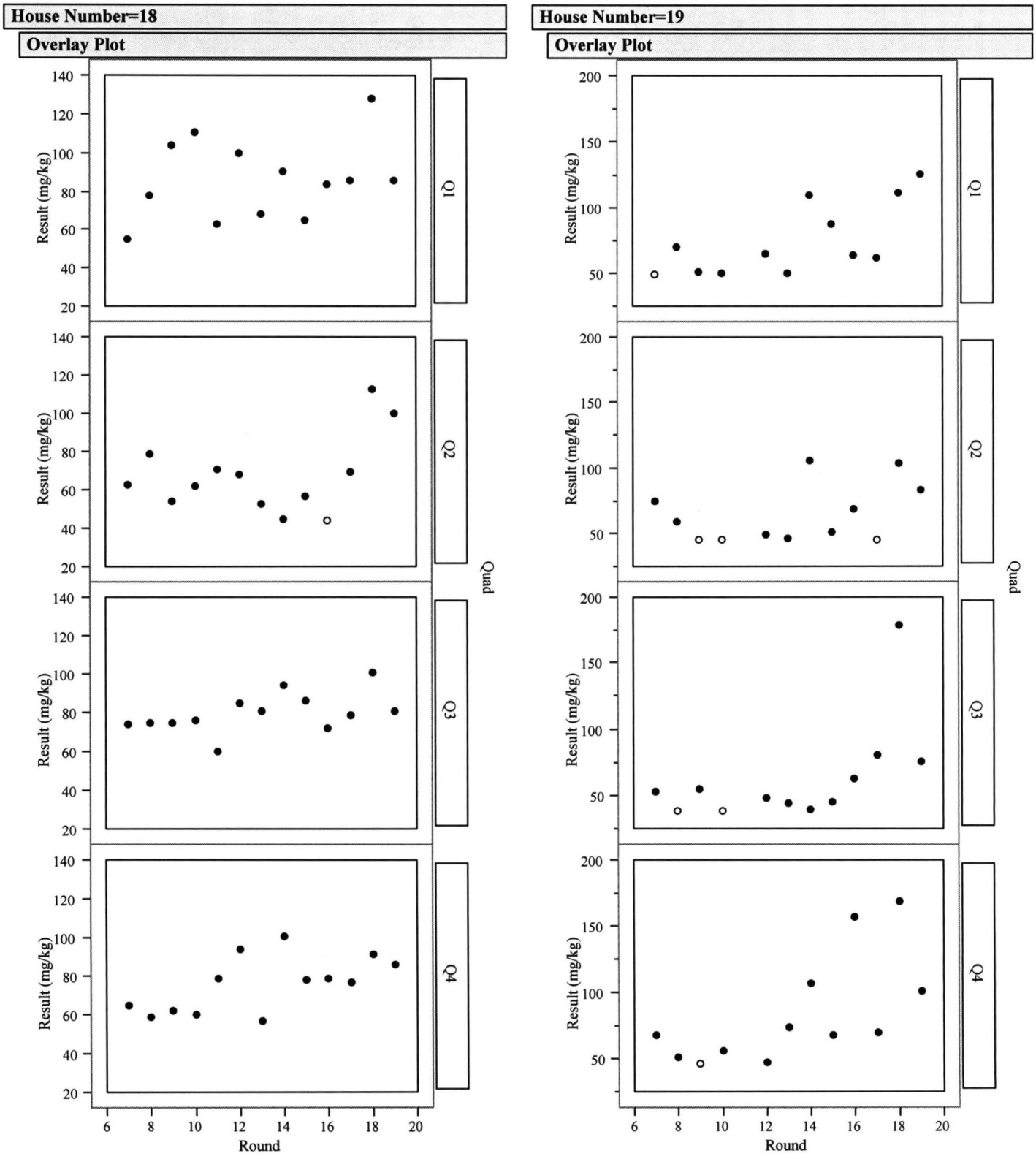

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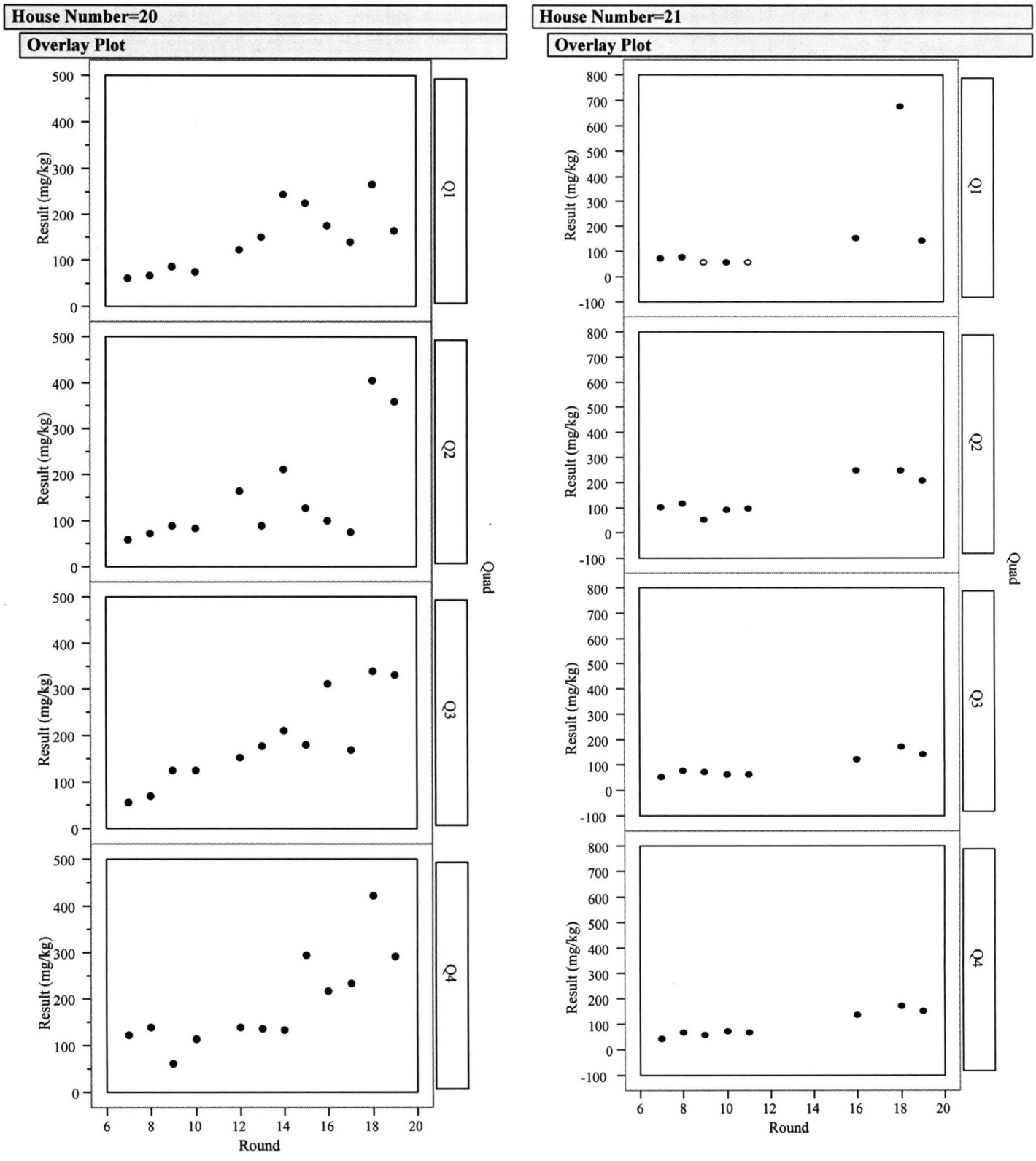

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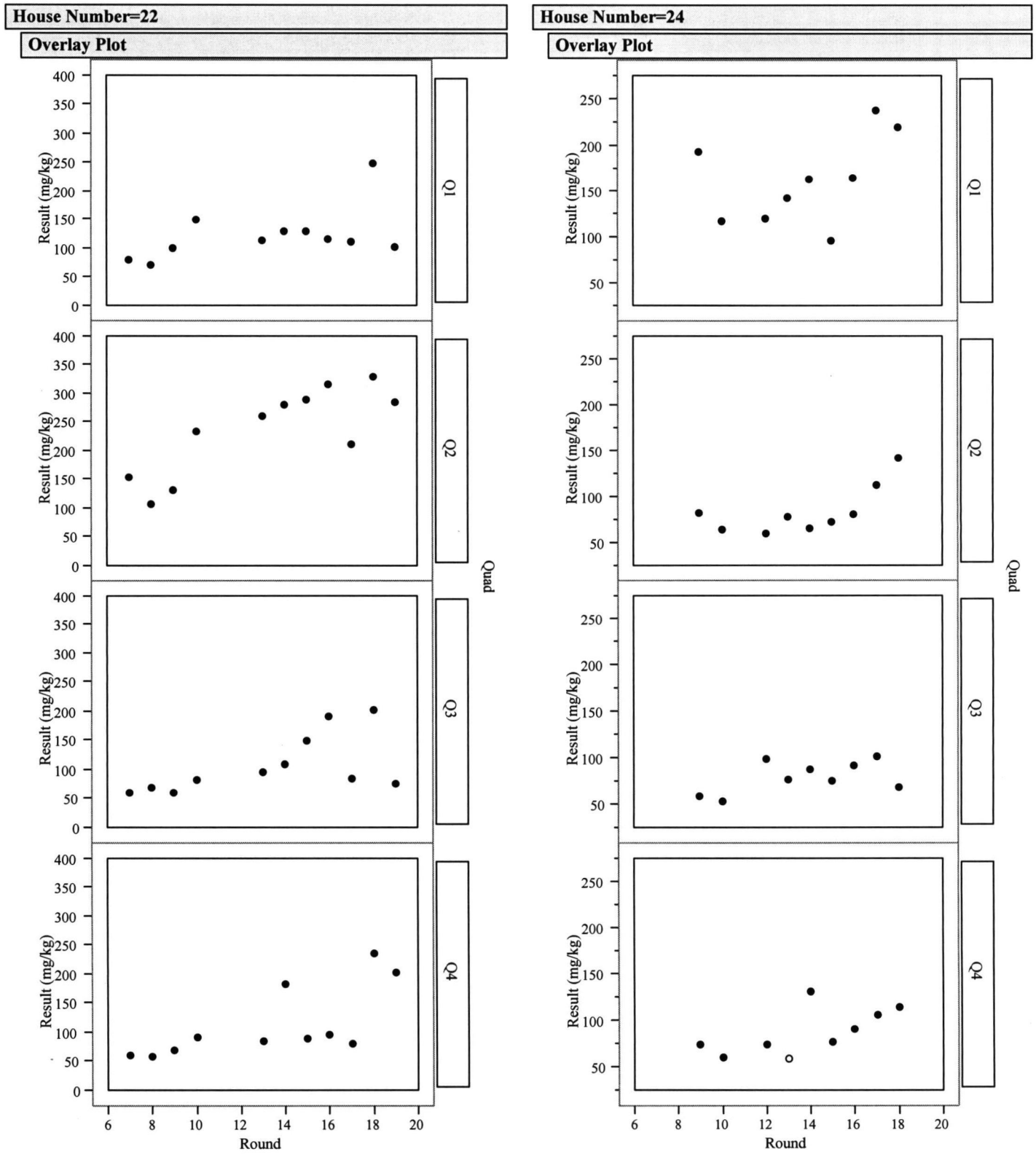

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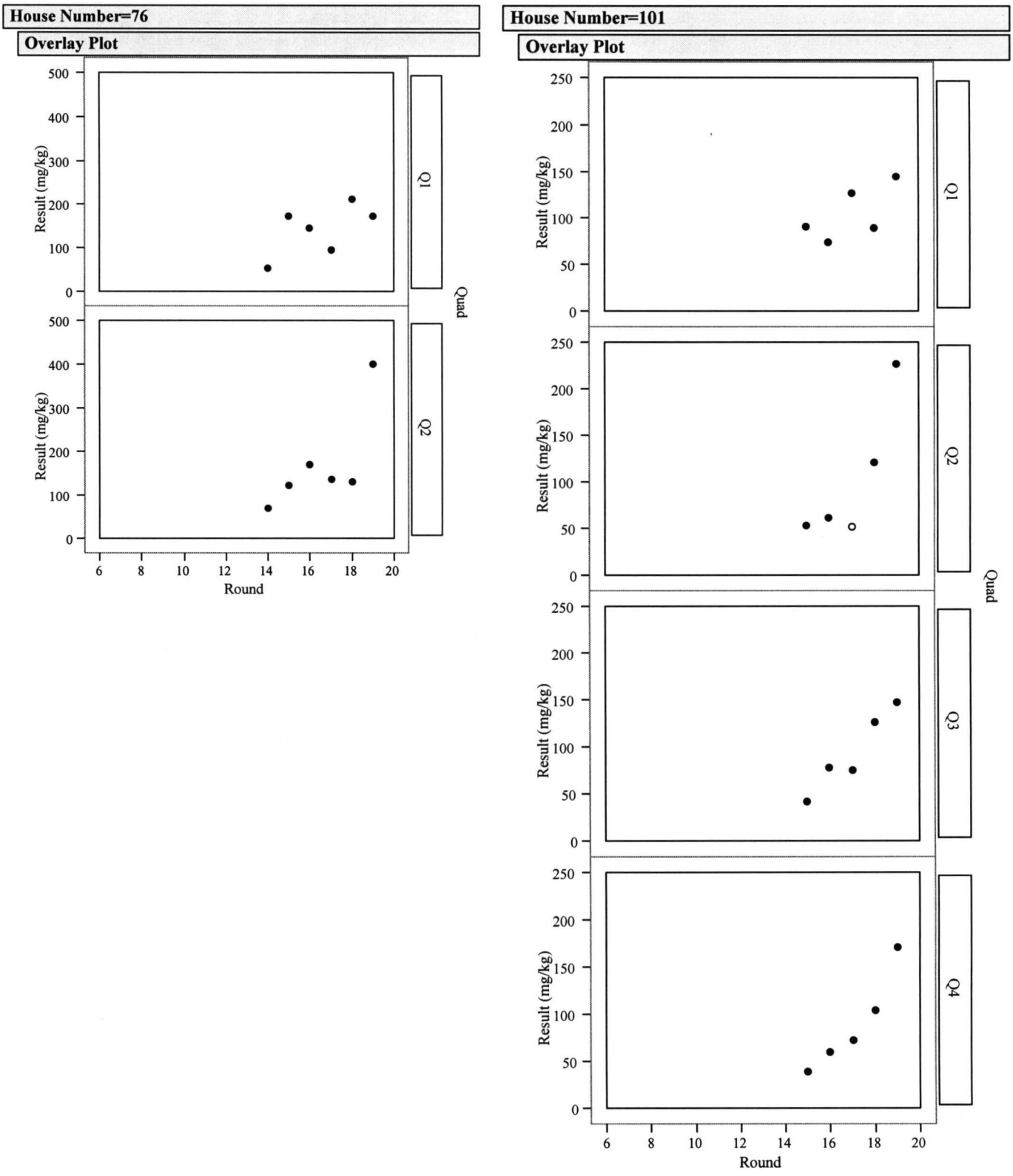

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